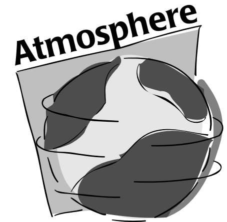
Introduction



Scientists are investigating the atmosphere. They want to understand and predict:

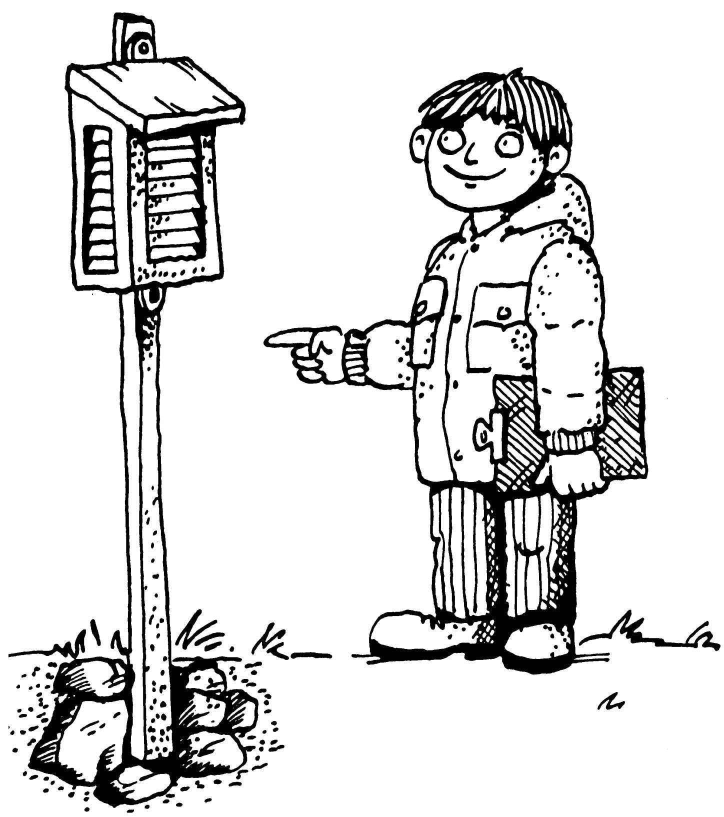
- Weather (the air temperature, rain, snow, relative humidity, cloud conditions, and atmospheric pressure and the coming and going of storms);
- Climate (the average and extreme conditions of the atmosphere); and
- Atmospheric Composition (the trace gases and particles in the air).

Each of these characteristics of the atmosphere affects us and our environment. What we wear and what we can do outside today depend on weather. Is it raining? Snowing? Sunny? Cold?

How we build our homes and schools, what crops we grow, what animals and plants naturally live around us all depend on climate. Does rain come mainly in winter or summer or every day? Do we get frost or snow? How long do dry spells last?

The composition of the atmosphere affects how our air looks and feels and how far we can see. On days when clouds don't completely cover the sky, does the sky look blue or milky? Does it ever have a brown tint? Do sunsets have lots of red color? All these are dependent on the composition of our air.

GLOBE scientists want several types of atmosphere data from schools to help in their investigations. As a GLOBE student, you can do research on the atmosphere, too. You can investigate your local weather, climate, and atmospheric composition and how these vary from place to place, season to season, and year to year. You will learn more about the air around you.



Why Investigate the Atmosphere?

We humans may live on land, but we live and move and breathe in the atmosphere. The atmosphere gives us the oxygen we breathe and carries off the carbon dioxide we exhale. The atmosphere filters out most harmful forms of sunlight and traps outgoing heat from Earth's surface. The atmosphere transports energy from the equator to the poles making the whole planet more liveable and brings the moisture evaporated from lakes and oceans to the dry land so that we have water to drink and to sustain our agriculture. We are creatures of the atmosphere and depend on its temperature, structure, composition and the moisture it carries.

Weather

On a day-to-day basis, we want to know many things about the weather we will encounter today. For example, we might like to know what the air temperature will be and whether it will rain so we can decide what type of clothes to wear; whether we need to take an umbrella with us when we go outside; or if we need to wear a hat and sunscreen to protect us from the sun's ultraviolet rays. We want to be sure the air we breathe is good for us. We want warnings so that we may protect ourselves and our property from severe storms.

Climate

We also want information about the atmosphere on a longer term basis. Farmers need to know if their crops will get enough rain. Ski resorts need to know if enough snow will fall. Insurance underwriters for areas struck by hurricanes would like to know how many hurricanes to expect in a given year and how strong they will be when they make landfall. Nearly everyone would like to know what the weather is going to be not only tomorrow or the next day, but next week, and what the climate will be six months, a year, or even ten years from now!

People have long said, "Everyone complains about the weather, but no one does anything about it." Today, scientists are working hard to understand and predict the full range of atmospheric phenomena, from storms to ozone. Atmospheric scientists study not only what is going on with the atmosphere today, but why it was a certain way in the past and what it will be like in the future. While controlling the weather is generally beyond human ability, the collective effects of human activity influence weather, climate, and atmospheric composition.

Scientific understanding of the atmosphere and the ability to forecast its future state grows through the application of fundamental laws and extensive observations. Since we care about the atmosphere on scales ranging from the individual farm to the entire globe and on timescales from a few minutes in severe storms to decades for the climate, vast quantities of data are needed.

Scientists Need GLOBE Data

People often think that scientists know what is happening in all parts of the world, but this is far from true. There are many regions where scientists have only the most general understanding of environmental factors such as air temperature and precipitation. Even in regions where there seems to be an abundance of data, scientists still do not know how much precipitation and temperature vary over relatively short distances. Official weather monitoring stations have contributed much data for a century or more in some locations while satellite technology has given us pictures of large areas every 30 minutes and global images at least twice daily for decades. Some areas have special monitors of atmospheric gases, and increasingly, airports monitor winds, not only at the ground, but up to heights of several kilometers. Despite all these wonderful efforts, there are gaps in coverage. The atmosphere varies significantly within these gaps, and GLOBE student measurements can improve the coverage for many types of observations.

Atmospheric conditions have an important impact on the types of plants and animals that live in a certain area, and even on the kind of soil that forms there. The measurements that students take for the GLOBE Atmosphere Investigation are important to scientists who study weather, climate, land cover, phenology, ecology, biology, hydrology, and soil.

The Big Picture

The Nature of the Atmosphere

Earth's atmosphere is a thin layer of gases composed of about 78% nitrogen, 21% oxygen, and 1% other gases (including argon, water vapor, carbon dioxide, and ozone). There are also solid and liquid particles called aerosols suspended in this layer. The atmosphere is held to the planet by gravity with the result that atmospheric pressure and density decrease with height above Earth's surface. See Figure AT-I-1.

Temperature also varies with height in the atmosphere (Figure AT-I-2), but in a more complex way than pressure and density. About half the sunlight shining on Earth passes all the way through the atmosphere and warms the surface. The warm ground then heats the air at the surface. Temperature generally decreases to heights of 8 to 15 km, depending on latitude. This defines the lower atmosphere or *troposphere* where most weather happens.

Ultraviolet sunlight is absorbed by oxygen to form the ozone layer and is also absorbed by ozone itself. This absorption warms the middle atmosphere, causing the temperature to rise with height from the top of the lower atmosphere to 50 km (the *stratosphere*) and then to fall with height to roughly 80 km (the *mesosphere*). Above this height, in the *thermosphere*, the density of the air is so reduced that many different phenomena begin to be important. At these heights, absorption of x-rays and extreme ultraviolet light from the sun ionizes the gases of the atmosphere and heats the air. The ions are affected by Earth's magnetic field and also by the solar wind. At great distances from the planet's surface, the atmosphere trails off into the *interplanetary medium*. The density of the atmosphere decreases until it is the same as that of interplanetary space.

There are differences in the atmosphere at different latitudes as well as different heights. The intensity of sunlight at Earth's surface varies with latitude. Sunlight is most intense in the tropics and least intense near the poles. The tropics are heated more than the poles, and the atmosphere along with the oceans transport heat from the equator toward the poles. The result is a large scale circulation of the atmosphere which is described in the *Earth As A System* chapter.

Through the motion of the atmosphere, all the different places on Earth are connected together on timescales of hours to days to months. Changes in one part of the world result in changes in other areas.

Figure AT-I-1

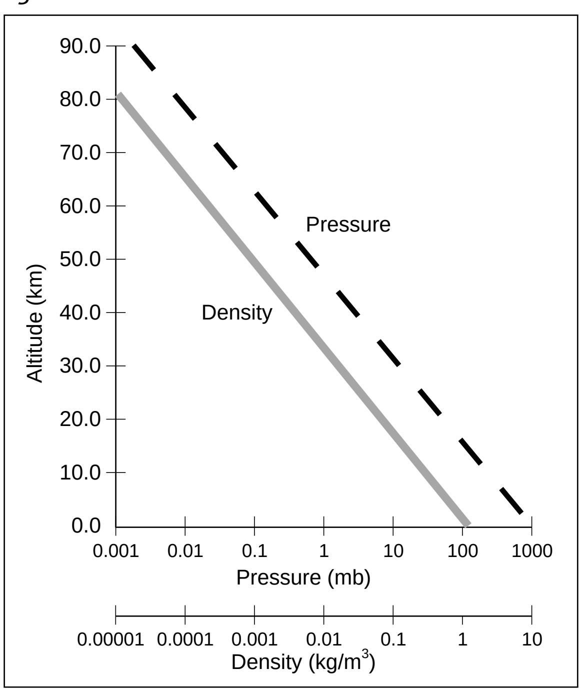
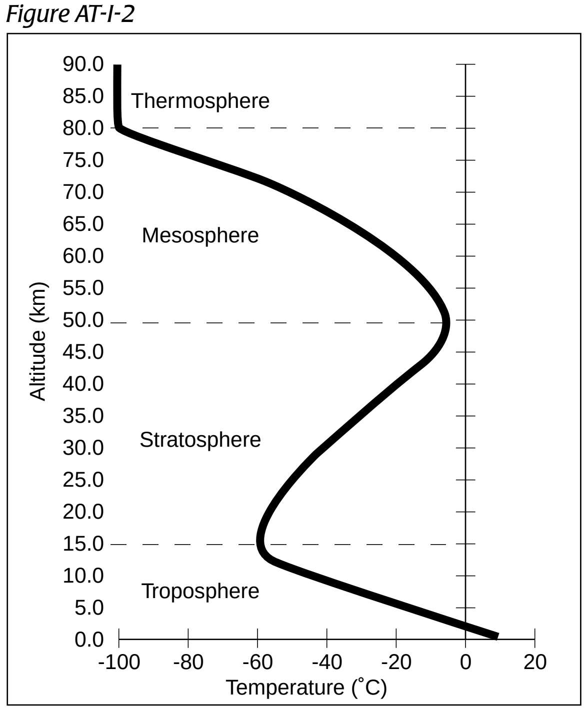


Figure AT-I-2



Weather and Climate, the Atmosphere Over Time

Weather and climate are not the same. By *weather* we mean what is happening in the atmosphere today, tomorrow, or even next week. By *climate* we mean weather averages, variability, and extremes over time. For example, in a certain city the current temperature may be 25˚ C; this is weather. If instead we were to look at the weather records for the past 30 years, we might find that the average temperature in that city on that particular day is 18˚ C (this is climate). We also might find that over this 30-year period the temperature in this city has ranged from as high as 30˚C to as low as 12˚C on that particular day. Therefore, the present temperature of 25˚C is not unusual.

When we study the history of Earth's climate, we notice that temperature and precipitation in any given region vary over time and that the composition of the atmosphere has changed. For example, images from certain satellites show that great rivers used to run through the Egyptian Desert. We also know that thousands of years ago, glaciers were present in places like New York City where today air conditioning is routinely used to cope with summer heat. If Earth was so different in the past, can we predict what might happen in the future? Predicting climate is a major goal of Earth Science today.

GLOBE Measurements

What Measurements Are Taken?

Different GLOBE measurements are useful in investigating weather, climate, and atmospheric composition.

Weather

Cloud Cover and Type
Barometric Pressure
Relative Humidity
Precipitation
Maximum, Minimum, and Current Temperatures
Wind speed and direction (if you have automated equipment)

Climate

Cloud Cover and Type
Relative Humidity
Precipitation
Maximum, Minimum, and Current Temperatures
Wind speed and direction (if you have automated equipment)
Complemented by:
Soil Temperature
Soil Moisture
Green-Up
Green-Down

Atmospheric Composition

Aerosol Optical Thickness
Relative Humidity
Precipitation (pH)
Surface Ozone
Supported by measurements of:
Clouds, Barometric Pressure, Wind Direction, and Current Temperature.

Individual Measurements

Cloud Cover and Type

Clouds play an important role in Earth's weather and climate. In the GLOBE cloud measurements students use their eyes to determine the percentage of the sky covered by clouds and the type of clouds in the sky. With the help of the *GLOBE Cloud Chart*, students categorize each cloud as one of ten types. The types of clouds in the sky often depend upon present or upcoming weather conditions; some clouds form only in fair weather, while others bring showers or thunderstorms. By paying attention to the clouds, students may soon be able to forecast the weather!

Pressure

Atmospheric pressure is a measure of the weight of the atmosphere pushing down on Earth's surface. It varies with the elevation and weather at a site. Students use an aneroid barometer (below 500 m elevation) or an altimeter (above 500 m elevation) to measure the atmospheric pressure at their site. Storms are usually associated with low pressure, so falling pressure indicates a storm is coming while rising pressure indicates fair weather is on the way as storms leave. By combining pressure data with their cloud observations, students may be able to forecast the weather at their school even more accurately than from the clouds alone.

Aerosol Optical Thickness

Small airborne liquid and solid particles, called aerosols, in the atmosphere affect whether the sky looks blue or milky, clear or hazy. They also influence the amount of sunlight that reaches Earth's surface. Using a sun photometer and a voltmeter to measure the intensity of sunlight reaching the surface, GLOBE students and scientists can determine aerosol amounts (aerosol optical thickness). Satellites infer this property of the atmosphere using remote sensing, while ground-based observations provide direct measurements to determine aerosol concentration. These two types of data complement one another, and student measurements can add greatly to the few ground-based professional monitoring stations currently collecting aerosol data.

Relative Humidity

The amount of water vapor in the air compared to the maximum amount of water vapor air at the same temperature and pressure can hold is referred to as relative humidity and is expressed as a percentage. Satellites can sense the amount of water in the atmosphere, but generally these measurements are averages over large regions (≥10s of kilometers). Humidity may vary over much a smaller distances. Using either a sling psychrometer or a digital hygrometer to measure relative humidity, GLOBE students can expand the total set of humidity data and help scientists to gain a better understanding of its variations on small scales.

Precipitation

Rain and snow vary significantly over distances less than 10 km. In order to understand the local, regional, and global water cycles, we must know how much precipitation falls at many different locations around the world. Student observations using rain gauges and snow boards help provide improved sampling of rain and snow amounts and support improved understanding of weather and climate.

In addition to measuring the amount of precipitation, GLOBE students measure the pH of rain and melted snow. Knowing the pH of precipitation that falls in a particular area is often essential to understanding the pH of the soil and water bodies in that area. Student pH measurements establish a local basis for tracking changes in the input of acidity to the environment and can help scientists better map the fate of atmospheric chemicals.

Temperature

Air temperature varies throughout the day in response to direct solar heating and from day to day as weather systems move around the globe. Average air temperature also changes with the seasons. Scientists want to know both the extremes of temperature and the average temperature for time periods ranging from 24 hours to a month, a year, or longer. GLOBE students measure maximum and minimum temperatures for a 24-hour period beginning and ending within one hour of local solar noon.

Scientists studying the climate of our planet are interested in finding out if the temperature at different places is changing, and if so, what patterns can be seen in these changes. Local temperature measurements, such as those taken by GLOBE students, aid scientists in answering these and other important questions regarding Earth's climate. Human settlement combined with variations in elevation and distance from water bodies produce local variations in temperature and GLOBE schools provide valuable detail for understanding changes even if there are official weather stations nearby.

Surface Ozone

Ozone is a highly reactive gas present in the air around us. Knowing the amount of ozone in the air is important for understanding the chemistry of the atmosphere and its effect on the health of plants and animals, including us. Ozone concentrations are measured in units of parts per billion (ppb) and can vary over small spatial scales. Local measurements are required for scientists to track these local variations in ozone concentrations in the atmosphere. GLOBE scientists have developed a straightforward technique for students to measure ozone at their schools by exposing chemically treated strips to the air and measure their change in color with a hand-held reader. These student observations complement and extend the limited number of ozone monitoring stations currently in existence.

Where are measurements taken?

All atmosphere measurements are taken at the Atmosphere Study Site. This site is usually located on school grounds and should be within easy walking distance of your classroom so that students can take data daily in a minimum of time. Generally, the more open the site the better. Significant obstructions should be avoided, including trees and buildings near the instruments.

If your school does not have a suitable ground level location for safe, permanent installation of atmosphere instruments, use of roof sites and automated equipment can be considered. Consult the Optional Protocols on the GLOBE Web site for more guidance.

When are measurements taken?

The GLOBE atmosphere measurements should be taken on a daily basis, at specific times of day. See Figure AT-I-3. Taking measurements at the same time of day, allows easier comparison of measurements made around the world. For

Figure AT-I-3

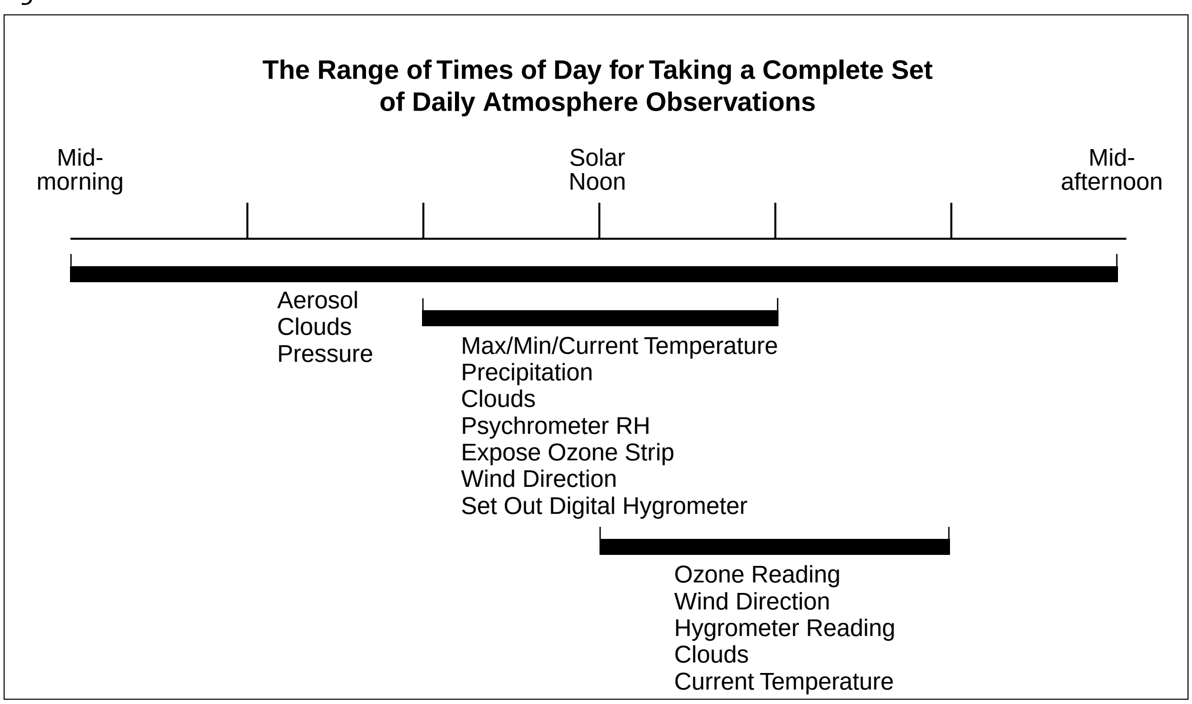


Table AT-I-1

Measurement	Taken within one hour of local solar noon	Measurements taken at other times
Cloud Cover and Type	Yes	Required in support of aerosol, ozone, and water transparency measurements; additional times are acceptable.
Aerosol	Sometimes for some latitudes and times of the year	When the sun is at least 30˚ above the horizon or at local solar noon when the sun doesn't reach 30˚ above the horizon; additional times are acceptable
Relative Humidity	Yes for the psychrometer; the digital hygrometer reading may be reported up to one hour later at the same time as the ozone measurement	Additional times are acceptable
Precipitation	Yes	No
Current Temperature	Yes	Required for comparison with soil temperature measurements and in support of aerosol, ozone, and relative humidity measurements; additional times are acceptable
Maximum and Minimum Temperature	Yes	No
Barometric Pressure	Not required	Within one hour of aerosol measurements if aerosols are measured; otherwise as convenient
Ozone	The observation is started at this time and completed one hour later	Other one-hour periods are acceptable in addition to the near-noon measurement

GLOBE, most atmospheric observations should be made within one hour of local solar noon, and readings of precipitation and maximum and minimum temperature are only acceptable if they are made within this 2-hour time period. Each of these measurements covers a roughly 24-hour period beginning within one hour of local solar noon on one day and continuing to within one hour of local solar noon on the next day. See Table AT-I-1.

Cloud observations, relative humidity readings and current temperature measurements are also taken within one hour of local solar noon, but these observations can be reported for other times of day as well.

Local solar noon is the key time for taking GLOBE atmosphere measurements. See the section on how to calculate solar noon. Does this mean that only classes that meet at that time can participate? No! Because these measurements do not require much time to take, students from classes that meet earlier or later in the day can be assigned to take measurements during their lunch break or during a mid-day recess.

Solar Noon

Solar noon is the term used by GLOBE for the time when the sun appears to have reached its highest point in the sky during the day. An astronomer, for example, would refer to the same time as *local apparent noon*. Solar noon generally is not the same as noon on your clock. The time of local solar noon depends on your location within your time zone, the time of year, and whether or not daylight savings time is in effect. Solar noon does occur, however, half-way between sunrise and sunset when the sun crosses the horizon. It is the point during the day when shadows are the shortest.

An easy way to determine local solar noon is to find a newspaper from your town or one nearby that gives times of sunrise and sunset and to calculate the average of these times. First, convert both times to 24-hour clock times by adding 12 to any p.m. times, then add the two times and divide by two. This is the time of solar noon. See Table AT-I-2.

How many students should be involved?

A single student can take any of the atmosphere measurements. However, it is a good idea to have a small group of students take readings so they can check each other. It also helps to have a partner to write down readings as they are made. Observations can either be taken by the group as a whole, or can be made individually and then compared. If the readings are made individually, the group must remember to empty the rain gauge and reset the thermometer only when all students are finished. GLOBE recommends teams of 3 students as ideal for taking most measurements.

Ideally, pH measurements are taken by three different groups of students using three different samples of rain or melted snow. In all cases, taking measurements of three samples is expected. These three results are averaged and compared as part of data quality control. Rotating groups through the class (or classes) on a periodic basis will give all students an opportunity to participate. Having multiple groups take precipitation or maximum and minimum temperature measurements at different times on the same day is discouraged because it opens the door to confusion in emptying the rain gauge, resetting the maximum/minimum thermometer, and reporting the data.

The estimates of cloud type and cloud cover are *subjective* measurements, so the more students involved in this task, the better. Each student should take his or her own readings; then, students should come to an agreement as a group. Do not be surprised if your students initially have difficulty with these estimates. Even seasoned weather observers debate which type of cloud they are seeing, or exactly how much of the sky is covered by clouds. As your students get used to these observations, they will begin to recognize the more subtle distinctions in cloud types.

Table AT-I-2

Example:	**1**	**2**	**3**	**4**
Sunrise (am or 24-hour clock are the same)	7:02 a.m.	6:58 a.m.	7:03 a.m.	6:32 a.m.
Sunset	5:43 p.m.	5:46 p.m.	8:09 p.m.	5:03 p.m.
Sunset (24-hour clock)	17:43	17:46	20:09	17:03
Sunrise + Sunset	24 hr 45 min	23 hr 104 min	27 hr 12 min	23 hr 35 min
Equivalent (so that the number of hours is even)	(unchanged)	24 hr 44 min	26 hr 72 min	22 hr 95 min
Divide by 2	12 hr 22.5 min	12 hr 22 min	13 hr 36 min	11 hr 47.5 min
Local Solar Noon (rounded to the nearest minute	12:23 p.m.	12:22 p.m.	1:36 p.m. or 13:36	11:48 a.m.

Note that this is an example of doing arithmetic in base 60.

Table AT-I-3

Measurement	Approximate Time required (in minutes)
Cloud cover and type	5 - 10
Aerosol including current temperature and clouds	15 - 20
Relative Humidity	5 - 10
Precipitation	5 - 10
Precipitation pH using paper	5
Precipitation pH using pen or meter including calibration	10
Handling of snow samples in the classroom for snow or snow pack water equivalent	5
Snow water equivalent once the snow has melted	5
Maximum, minimum, and current temperature	5
Barometric Pressure	5
Ozone deploying the strip	5
Ozone reading the strip and taking current temperature	5 - 10
Entire set of local solar noon measurements: clouds, relative humidity, precipitation amount and pH, temperature, and deploying the ozone strip	15 - 25

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How long does it take to do the measurements?

The amount of time required to take the atmosphere measurements will vary depending on the location of your Atmosphere Study Site(s), how many students are on the team taking the data, student age and familiarity with the measurements, and the actual conditions encountered on a given day. See Table AT-I-3.

Getting Started

You and your students can investigate the atmosphere at your own study site and cooperate with scientists and other students to monitor the global environment. The atmosphere is one critical component of the global environment, and you can help compile a global database of atmospheric measurements that will aid in the long-term understanding of how the atmosphere is changing.

You and your students can approach the study of the atmosphere in many different ways, but three major themes that can be studied using the measurements you take in GLOBE are: weather, climate, and atmospheric composition. The sections below describe how the GLOBE atmosphere protocols contribute to an understanding of each of these areas that may be part of your curriculum.

Weather

Perhaps your students study weather. If so, their GLOBE work can become an integral part of this learning. By "weather" we mean the current condition and short-term changes in the atmosphere. Students may be familiar with weather reports and forecasts, and you could introduce the GLOBE protocols by asking them to explain what they think "weather" means. They will probably mention things like the temperature, whether it's raining or snowing, whether it's cloudy, whether it's windy and the direction of the wind. Some students may also mention barometric pressure, cloud types, and humidity. All of these are aspects of what meteorologists mean by "weather," and all can be measured in GLOBE. Thus, by doing GLOBE measurements, your students can begin to measure, monitor, study, track and forecast the weather.

Here is a suggested sequence for introducing GLOBE measurements through the study of weather.

1. Cloud measurements are the easiest place to start. They require only a cloud chart and the human eye. Two learning activities are good to do before beginning

the actual cloud cover and cloud type protocols:

- *Observing, Describing, and Identifying Clouds*
- *Estimating Cloud Cover: A Simulation*

2. In order to submit your cloud cover and cloud type observations, you need to define an Atmosphere Study Site and submit site definition data to GLOBE. You may want do this before you set up the instrument shelter, so that if you experience delays in getting your shelter set up, you can still define your site and submit your cloud data.
3. You also can begin taking relative humidity and barometric pressure readings without having the instrument shelter.
4. Current temperature measurements can also be taken without the instrument shelter. When you are able to install the instrument shelter you will be able to take and submit daily maximum and minimum air temperature measurements.
5. Taking and submitting liquid precipitation measurements requires the installation of a rain gauge on a post, but you can measure snow depth and liquid equivalent without the installation of the rain gauge.
6. If you use certain automated weather instruments, you can add wind speed and direction to your set of GLOBE data following optional protocols.
7. You must check the calibrations of your instruments (thermometers, barometer or altimeter, sling psychrometer) before you begin.

Keep a permanent record of your GLOBE data at your school. The atmospheric data that students gather should not only be submitted to the GLOBE data server, but should also be recorded permanently in the GLOBE Data Log for the school. A notebook of the data sheets filled in by the students can serve this purpose. See the Implementation Guide chapter for a description of the Data Log and its importance. Students should take pride in the fact that they are contributing to a long-term atmospheric data set at their school.

As your local data set grows, you should engage students in looking at their data. Each protocol of this chapter includes a *Looking At the Data* section, which outlines how to judge whether the data are reasonable and describes what scientists look for in data of this type. Most of them also contain a sample student investigation using data from the protocol. Review these sections for ideas on how to use GLOBE data for student learning about weather.

Try your hand at forecasting. One interesting way for students to use the data they collect is to try to make weather forecasts using their own data and to compare their forecasts to those of professional meteorologists. Who is more accurate? What data are most helpful in making a prediction? What additional data do the professionals use that are not available to students? There are many interesting questions that can be pursued.

Climate

Climate is another major topic that your students may study and that can be explored using GLOBE measurements and data. "Climate" is the long-term trend of the atmosphere and other variable aspects of the environment. There is an old saying, "Climate is what you expect. Weather is what you get." Climate refers to averages and extremes of temperature, clouds, precipitation, relative humidity and their annual patterns.

Through looking at GLOBE data from their own school and from other sites around the world, students can begin to gain an appreciation for climate patterns and what causes them. They can notice seasonal trends, variations based on latitude, and variations based on proximity to large bodies of water. By using the GLOBE student data archive, students can compare the climate of their school, nearby schools, and schools in widely varying spots around the globe.

Students can take it as a challenge to build a long-term database that describes the climate of their locality. Most newspapers publish monthly summaries of the weather and compare them to climatic expectations. If not, then consult the meteorologist at your local airport or radio/TV station. These climatologies can provide the basis for interesting discussions of what is "normal" for your locale. Has it been a wetter than normal month? Hotter? Cooler? Cloudier? Using their GLOBE data and local climatic information, students can begin to answer these questions and think about how their climate may be changing.

To study climate your students will use the same atmosphere protocols as for weather, except they will not need to measure barometric pressure. Routine measurements of daily amounts of precipitation and maximum and minimum air temperatures are critical for climate study. Measurements of soil temperature and moisture and of phenology are also important in studying climate. The temperature of water bodies and when they are dry or frozen are also useful. Students can think about and debate which of the GLOBE measurements are most important for describing the climate.

In order to study climate using GLOBE measurements, you will want your students to access data from other schools using the GLOBE student data archive. GLOBE provides graphing tools online and the ability to download a school's data as a table that can be imported into other data analysis programs such as a spreadsheet.

Atmospheric Composition

Perhaps your students study the composition of the atmosphere. They can use two of the GLOBE atmosphere protocols – aerosols and surface ozone – to enhance their study. Both of these can also be considered aspects of the weather and climate. Aerosols affect visibility and the passage of sunlight and heat through the atmosphere while ozone levels have short and long term effects on plant and animal life and long term effects on all materials exposed to the atmosphere.

Both protocols can be carried out without the installation of any permanent equipment, so even if you cannot install an instrument shelter and a rain gauge, you can still do these two measurements. However, for the surface ozone protocol you will need to measure cloud cover and type, wind direction, and current temperature (using the alternative protocol that does not require the instrument shelter). For the aerosol protocol you will need to record cloud cover and type and may measure barometric pressure or obtain values from other sources or from GLOBE.

Getting Ready

To prepare yourself to lead students through an atmosphere investigation using GLOBE, read the introductory sections of the Atmosphere chapter of the GLOBE Teacher's Guide. Familiarize yourself with the scientific background information provided. Then take a look at the sections *What Measurements are Taken* and *Measurements Logistics*. Decide which theme or set of questions your students should pursue and which measurements are appropriate for their study. Think about how to introduce GLOBE to your students as an opportunity for them to participate with scientists and other students in monitoring the global environment, and think about what projects and analyses your students can accomplish as they approach the atmosphere through the lens of weather, climate, or atmospheric composition.

If age appropriate, copy and distribute to students the sections of the chapter entitled *Why Investigate the Atmosphere* in order to give them an understanding of why each measurement is scientifically important. Discuss the importance of a global database to understand the environment and how they can contribute to this by submitting consistent accurate data to the GLOBE Data Server. Engage the students in asking questions they can answer through taking and looking at data.

Review the specific protocols and plan which measurements your students will take. Feel free to start with an easily sustained level of effort and then expand.

Obtain the instruments you will need and calibrate them if necessary. Set up your instrument shelter and rain gauge if you will be measuring maximum and minimum temperature and liquid precipitation.

Make photocopies of all the data sheets and field guides that students will need.

Then, begin doing the GLOBE Atmosphere Investigation!

	Basic Protocols				Adv. Protocols	
National Science Education Standards	Clouds	Humidity	Precip.	Temp.	Aerosol	Ozone
Earth and Space Science Concepts						
Weather can be described by quantitative measurements		■	■	■		■
Weather can be described by qualitative observations	■					
Weather changes from day to day and season to season	■	■	■	■		■
Weather varies on local, regional, and global spatial scales	■	■	■	■		■
Clouds form by condensation of water vapor in the atmosphere	■					
Clouds affect weather and climate	■					
Precipitation forms by condensation of water vapor in the atmosphere						
The atmosphere has different properties at different altitudes	■					
Water vapor is added to the atmosphere through evaporation and transpiration from plants	■	■				
The atmosphere is composed of different gasses and aerosols					■	■
The sun is a major source of energy for changes in the atmosphere					■	
The diurnal and seasonal motion of the sun across the sky can be observed and described					■	
The water vapor content of the atmosphere is limited by pressure and temperature		■				
Condensation and evaporation affect the heat balance of the atmosphere						
Materials from human societies affect the chemical cycles of Earth						■
Dynamic processes such as Earth's rotation influence energy transfer from the sun to Earth						
Physical Science Concepts						
Materials exist in different states - solid, liquid, and gas	■	■	■			
Heat transfer occurs by radiation, conduction, and convection						
Substances expand and contract as they are heated and cooled						
Geography Concepts						
The temperature variability of a location affects the characteristics of Earth's physical geographic system				■		
The nature and extent of cloud cover affects the characteristics of Earth's physical geographic system	■					
The nature and extent of precipitation affects the characteristics of Earth's physical geographic system			■			
Human activities can modify the physical environment					■	
Water vapor in the atmosphere affects the characteristics of Earth's physical geographic system		■				
Measurements of atmospheric variables help to describe the physical characteristics of an environment						
The physical characteristics of a location depend on its latitude and relation to incident solar radiation						
Geographic visualizations help to organize information about places, environments, and people						
General Science Concepts						
Scale models help us to understand concepts						
Visual models help us to analyze and interpret data						

Optional Protocols		Learning Activities										
Pressure	Auto. Soil/Air	Cloud Watch	Observe Clouds	Study Instr. Shelter	Build a Thermo-meter	Draw Visuals	Use Visuals	Contour Map	Make a Sundial	Hazy Skies	Air Mass	Model ppv
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	Basic Protocols				Adv. Protocols	
National Science Inquiry Standards	Clouds	Humidity	Precip.	Temp.	Aerosol	Ozone
General Scientific Inquiry Abilities						
Use appropriate tools and techniques						
Construct a scientific instrument or model						
Identify answerable questions	■	■	■	■	■	■
Design and conduct scientific investigations	■	■	■	■	■	■
Use appropriate mathematics to analyze data	■	■	■	■	■	■
Develop descriptions and explanations using evidence	■	■	■	■	■	■
Recognize and analyze alternative explanations	■	■	■	■	■	■
Communicate procedures and explanations	■	■	■	■	■	■
Specific Scientific Inquiry Abilities						
Use a thermometer to measure temperature		■		■		
Use a cloud chart to identify cloud type	■					
Estimate cloud cover	■					
Use a rain gauge to measure rainfall and rain equivalent of snow			■			
Use pH paper, pens, or meters to measure pH			■			
Use meter sticks to measure snow depth			■			
Use a sun photometer and voltmeter to measure the amount of direct sunlight					■	
Use ozone strips and a strip reader to measure in situ ozone concentrations						■
Use a weather vane to identify wind direction						■
Use a barometer or altimeter to measure barometric pressure						
Use a hygrometer or sling psychrometer to measure relative humidity		■				

Optional Protocols		Learning Activities										
Pressure	Auto. Soil/Air	Cloud Watch	Observe Clouds	Study Instr. Shelter	Build a Thermo- meter	Draw Visuals	Use Visuals	Contour Map	Make a Sundial	Hazy Skies	Air Mass	Model ppv
						■	■	■			■	■
					■				■			■
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Educational Objectives

Students participating in the activities presented in this chapter should gain scientific inquiry abilities and understanding of a number of key concepts. These abilities include the use of a variety of specific instruments and techniques to take measurements and analyze the resulting data along with general approaches to inquiry. The key concepts included are outlined in the United States National Science Education Standards as recommended by the US National Research Council and include those for Earth and Space Science and Physical Science. The Geography Concepts are taken from the National Geography Standards prepared by the National Education Standards Project. Additional Enrichment Concepts specific to the atmosphere measurements have been included as well. The gray box at the beginning of each protocol or learning activity gives the key concepts and scientific inquiry abilities covered. The following tables provide a summary indicating which concepts and abilities are covered in which protocols or learning activities.

Educational Assessments

Two sets of assessment materials are provided in the *Appendix*. The first set are in a spreadsheet-like format and are designed to test the student's formative understanding of how to take the measurements described in each protocol. The spreadsheets may be used either as a self-assessment or teacher assessment tool. The questions provide a means to evaluate how well the student understands the intrinsic measurement procedures, the influence of the environment on the measurement, and the abilities to collect, record and archive the data. The second set are designed as summative tests to evaluate the level of understanding of the science concepts incorporated in the protocols and learning activities. The assessments cover investigation areas that focus on each protocol and more general conceptual issues, such as weather and climate that relate to the relationship among two or more measured variables. General rubrics for assessing the quality of the student's understanding are provided in the *Implementation Guide*.